High efficiency and simple technique for controlling mechanisms by EMG signals

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Summary - This article reports the development of a simple and efficient system that allows control of mechanisms through electromyography (EMG) signals. The novelty about this instrument is focused on individual control of each motion vector mechanism through independent electronic circuits. Each of electronic circuit does positions a motor according to intensity of EMG signal captured. This action defines movement in one mechanical axis considered from an initial point, based on increased muscle tension. The final displacement of mechanism depends on individual's ability to handle the levels of muscle tension at different body parts. This is the design of a robotic arm where each degree of freedom is handled with a specific microcontroller that responds to signals taken from a defined muscle. The biophysical interaction between the person and the final positioning of the robotic arm is used as feedback. Preliminary tests showed that the control operates with minimal positioning error margins. The constant use of system with the same operator showed that the person adapts and progressively improves at control technique.

1. Introduction

From the beginnings of history, human beings have used the knowledge acquired to develop some kind of technology to improve their health and living conditions. The implementation of mechanisms has improved and extended motor skills of people [1]. The engineering problem is to design techniques for controlling these machines. In some cases is not possible to implement manual control and in other cases the implemented designs are so complex that generate a relatively slow response [2].

This project makes a contribution on subject of robotic equipment control using advantage muscle activity [2] [3]. The knowledge development on design of cybernetic systems efficient [3] contributes to improving the applicable technology in many fields. Among other applications, the medical problems solution in people with disabilities [4]. The benefits of implementing these mechanisms in therapeutic recovery techniques could be of great importance.

With the available technical capacity at regional level, a biological-mechanical interface has been designed for positioning a robotic arm (RA) with movement in two axes [5]. The RA final positioning depends on EMG signals [3] [6] captured of person who acts as system operator.

The main goal of this project is to control each RA axis independently. In that sense the movement on each axis is executed from the amplitude level of signal captured at particular muscle section. Thus, a

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specific muscle tension is reflected as RA positioning in the respective axis. The idea is to train the operator to achieve the desired positioning from control exercised over the corresponding muscles.

2. Methodology

The RA consists of a mechanical structure with two freedom degrees. The mechanism allows to arm termination move at any point on a plane defined by Cartesian axes (X, Y) [7], within a plane space of (20,20) centimeters (cm). The travel in each axis is performed independently and depends on the action of independent motors. One motor for each axis.

The control system works with two identical and independent electronic circuits. Each electronic circuit drives a motor and is responsible for the movement in one axis. Given that the circuits for controlling movement on the two axes are same; this paper presents the explanation of components that handle the movement in one axis.

The circuit response depends of electromyography signal picked up from muscle specific on system operator. The Fig. 1 represents the sequence of different steps making up the control of a freedom degree.
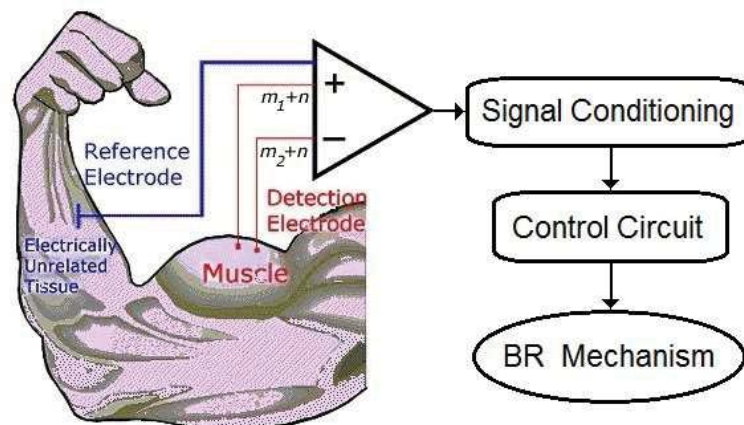

Fig. 1, RA control for a freedom degree.

2.1. Working principle

As seen in Fig 1, the system consists of four parts: the biopotential amplifier, the signal conditioning stage, the control circuit and the RA mechanism. The different elements are arranged for acquiring and conditioning of EMG signal. Then the system checks and generates the corresponding mechanical movement.

2.2. Biopotential Amplifier

 This step consists of a differential amplifier [8] [9] with a high common-mode rejection ratio (CMRR) [10], designed for capturing EMG signal [3]. This circuit can receive signals of amplitude between 0.01 and 100 millivolts (mV) in a bandwidth from 10 to 2000 Hz. The electrical circuit of Fig. 2 is formed by three operational amplifiers: A1, A2 and A3. A1 and A2 carry out the amplification of the muscle signal which are simultaneously taken, with surface electrodes placed on the skin.

This circuit improves of rejection by the device of unwanted input signals common to both input leads. Given that m1+n and m2+n are input signals, the difference between m1 and m2 signals make up the EMG and the n is the common mode voltage. A3 amplifies the potential difference between the two measurements to obtain only the desired signal.
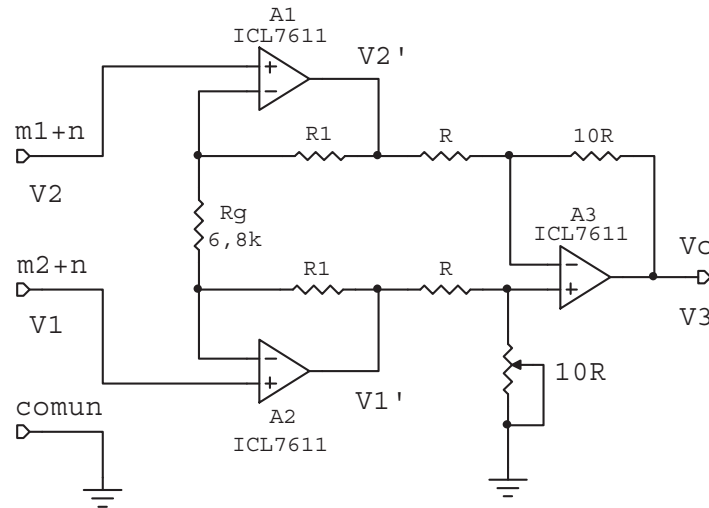
Fig. 2, Biopotential amplifier circuit

In performance tests the signals received from the pectoral muscles were used for driving instrument operator. The selection of these muscles was motivated to test the ability of disabled persons who have only motor activity in theirs torso.

Fig. 3 shows 28 seconds of EMG signal acquisition picked up with the Fig. 2 circuit. The signal was taken from the right pectoral muscle. The figure presents 6 contraction and relaxation efforts of different intensity and duration. These muscles are used to verify the usefulness of instrument on people with disabilities and have motor activity only in his torso.
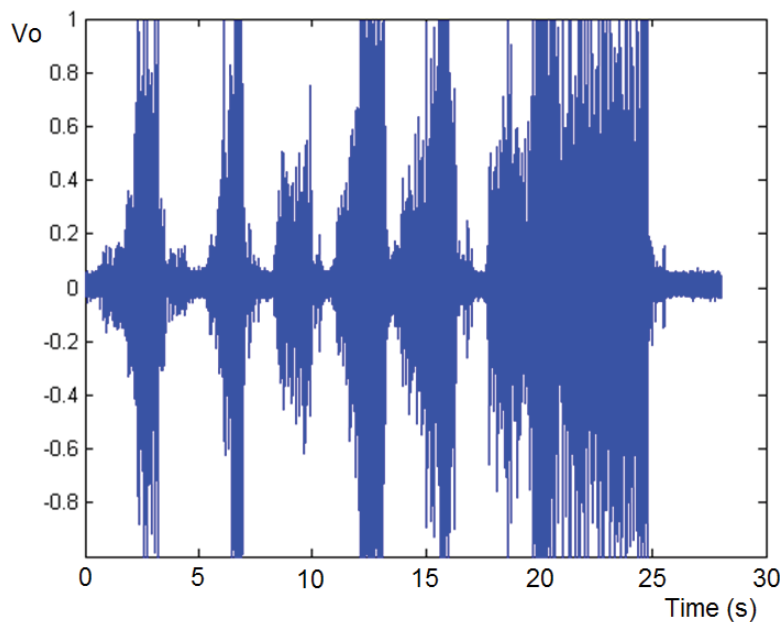

Fig. 3, EMG signal captured.

The digitization signal displayed in Fig. 3 was done with a data acquisition board at 20,000 samples per second with 16 resolution bits. The signal digitization is carried out in order to certify the system working through its computer analysis [11].

2.3. Signal conditioning

The signal conditioning is performed in order to capture only the generated amplitude-variation due to muscular tension. First the signal is rectified to obtain the positive components. Then low-pass filtered retrieves only the envelope [11]. The Fig. 4 diagram shows the electrical circuit designed for this purpose.
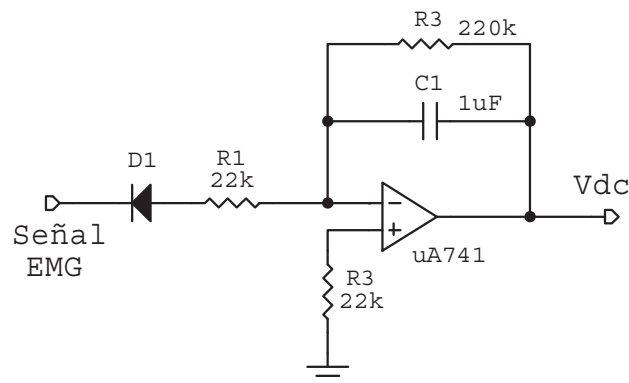

Fig. 4, Signal conditioning circuit.

The captured signal allows certify the performance of each stage. The signal identified as Xn in Fig. 5, shows the result of passing the Fig. 3 signal by rectifier diode, D1 identified in the circuit Fig. 4. The signal Yn in Fig. 5, presents the output defined as Vdc in Fig. 4 circuit.
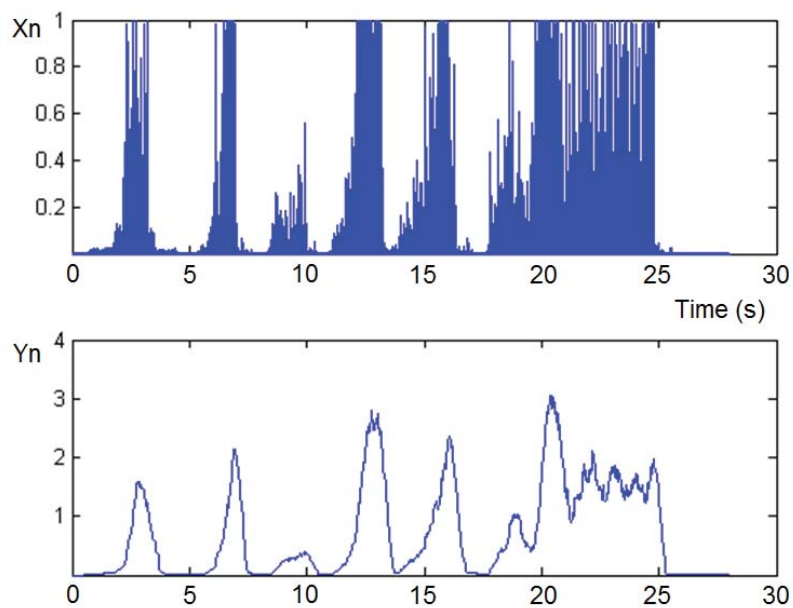

Fig. 5, Rectified and filtered EMG signal.

2.4. Control stage

The circuit showed in Fig. 6, consists of an electronic control of closed loop. It works by continuously correcting of difference generated between the input signal and the provided signal by potentiometer identified as RV1. The RV1 potentiometer is coupled to corresponding axis of mechanism, thus its resistance value is adjusted with changes in position of RA. This loop is to be able to define the position of the RA location continuously in the corresponding axis.
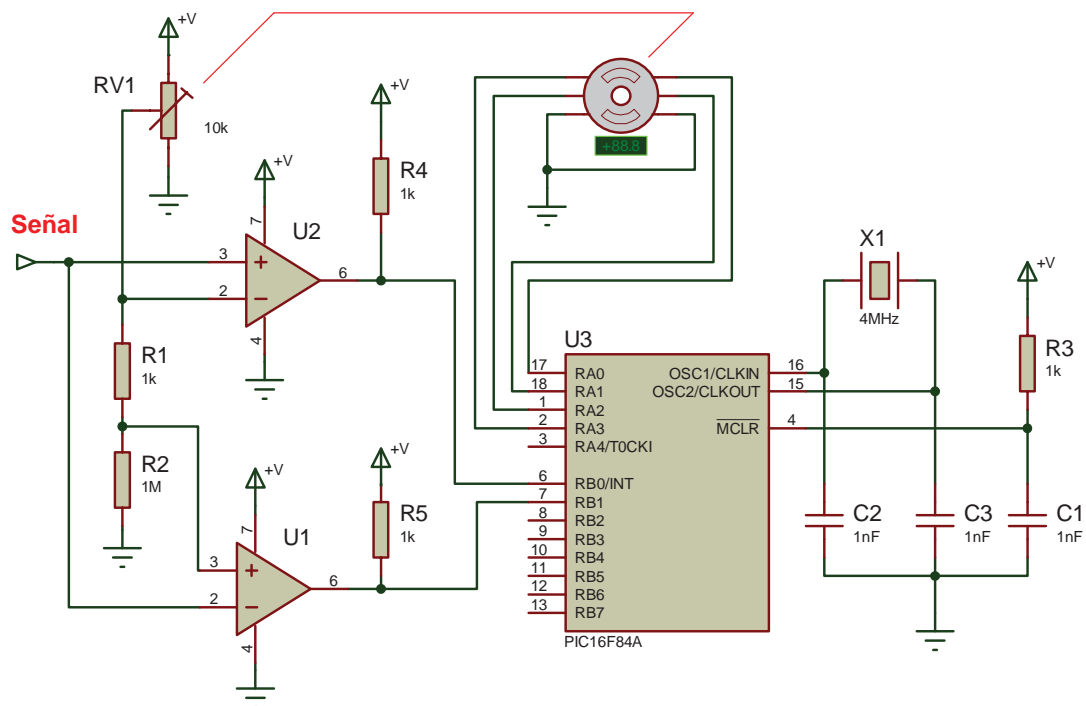

Fig. 6, Control circuit with microcontroller.

The U1 and U2 devices at Fig. 6 are comparators circuits [11]. The algorithm installed in PIC16F84 microcontroller [12] identifies the state of U1 and U2 comparators, with the aim of locating the position of AR.

The Fig. 7 shows a simplified diagram of microcontroller algorithm. When this software is running, checks the RB0 and RB1 inputs corresponding to U1 and U2 comparators. This is done in order to increase or decrease the pole corresponding to stepper motor for generating forward or backward movement on mechanism. This action corrects the difference between amplitude value of input signal and RV1 voltage. The microcontroller output is connected to four power transistors for motor current drives. To simplify the diagram, these transistors it is not shown in Fig. 6.

The control circuit, which in turn it is working in connection with the other system elements, allows that the mechanical activity of RA can be constantly adjusted for EMG signal. This condition increases the motor steps when input signal amplitude is greater than reference and return the motor rotation when signal amplitude decreases.
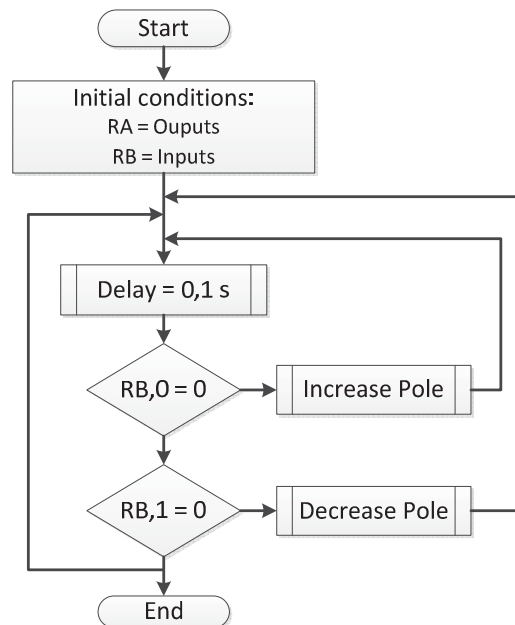
Fig. 7, Block diagram of control algorithm.

3. Results

When the subject under test performs a muscle voluntary contraction, it is noted a movement of RA in corresponding axis. The positioning depends directly of muscle tension intensity from the subject. When the operator uses the two control circuits connected to two individual body muscles it is observed that is capable of positioning the RA at any point on the plane (X,Y) the mechanism.

4. Discussion of results

Preliminary results showed it is feasible make up a control for handling mechanical devices from myographic signals.

The most interesting of test emphasizes that the simplification of system has achieved high efficiency levels at real-time responses with minimal risk of electronics failures.

Is a design with few components enabling high miniaturization, thereby is saving space and reducing weight.

In initial stage is noted that the system operator presented difficult for coordinate muscle activity at RA control. But, constant practice allowed efficiency increase at conducting control.

5. Conclusion

From the depths of history, the Man has dreamed about of controlling machines which only use human will and desires to move parts and mechanisms.

Preliminary tests showed that the implemented method can be used in the management of motorized machines using EMG signals.

It also was possible to obtain a response to voluntary muscular effort without having first running physical movement. Therefore, it was showed that it is really possible handle any mechanical device even if the operator is not to be able to do joint movement.

Day after day, the number of disabled is rising through over the world, for this reason is very important to develop new technologies of prosthesis which fit of the best way to biomechanical functions of human being.

Additionally, case studies are presented where analysis factors are critical, such as myographic applications in relation to athletic performance [13]. It should also take into account the technological challenge for develop control system to facilitate the use and management of very complex instruments and mechanisms.

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